Book of Abstracts

From the Lab to the Market

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33rd PSI Electrochemistry Symposium

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Paul Scherrer Institut
Auditorium West
5232 Villigen PSI, Switzerland
The PSI Electrochemistry Laboratory

Our Mission

Advancement of electrochemical energy storage and conversion by

- developing novel electrochemical materials, cells and devices
- providing insight into electrochemical materials, cells and device properties.

PSI’s Electrochemistry Laboratory is Switzerland’s largest Center for Electrochemical Research. Our mission is to advance the scientific and technological understanding of electrochemical energy storage and conversion specifically in the context of a sustainable energy system, in which renewable energy is required to be stored in secondary batteries or chemicals as e.g., hydrogen and (re-)converted into electricity. Our applied fundamental R & D, hence, is focused on devices like secondary batteries – specifically Li-based systems –, supercapacitors, polymer electrolyte fuel cells and electrolyzers, respectively.

As a Research Institute’s Laboratory we are bridging the gap between fundamental science and applied engineering by combining both academically as well as industrially relevant questions. For all outlined devices we not only develop fundamental understanding of materials on atomic and molecular level (electrochemical materials sciences and electrocatalysis), but also on the applied development of technical cells and devices, e.g., fuel cell systems.

On all technical complexity levels, we are developing and utilizing advanced in situ diagnostic tools to gain insights on properties and processes from the nanometer to the centimeter scale, respectively, often making use of PSI’s unique large scale facilities.
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Oral Presentations

"From the Lab to the Market"

33rd Electrochemistry Symposium
Glass Protected Li Metal Electrodes for Next Generation Rechargeable Batteries

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In the late 1980’s a number of universities and companies and were actively involved efforts to develop and commercialize rechargeable lithium metal batteries. Unfortunately, the formation of high surface area lithium associated with the inefficient stripping and plating of lithium metal in liquid electrolytes doomed the commercial prospects for these battery systems. Not surprisingly, battery developers looked for alternative solutions for the rechargeable battery market, leading ultimately to the commercial introduction of Li-ion technology in 1991. Although Li-ion battery technology has benefited from steady incremental improvements since that time, the market demand for the next generation of disruptive battery technology remains strong. Over the past several years R&D efforts focused on next generation battery technology have covered a broad spectrum of alternative anodes and cathodes as well as the possibility of all solid-state structures and it is not yet clear which of these strategies will lead to commercial success. With regards to lithium-based technologies, there is little doubt that replacing the carbon anode in Li-ion cells with a lithium metal electrode that exhibits highly efficient cycling and safe behavior would lead to a dramatic increase in energy density (Wh/l and Wh/kg). Attempts to solve the Li metal cycling problem have included the use of ionic liquids, polymer electrolytes, gel polymer electrolytes, and even combinations of ionic liquids with polymer electrolytes, but it is unclear why any of these approaches should fundamentally stop the formation and propagation of lithium dendrites, and to the best of our knowledge, they do not. Polymer electrolytes have insufficient mechanical strength to prevent dendrite growth\(^1\). Based on a careful analysis of the literature and our own internal research and development on protected lithium electrodes, we believe that the solution to the Li metal dendrite problem lies in the use of dense, highly conductive inorganic membranes. To date, the only commercial examples of high cycle life lithium metal batteries are thin-film cells made through sequential sputter deposition, and these cells demonstrate more than 10,000 cycles to 100% depth of discharge (although at uA/cm\(^2\) capacities). In this presentation we will examine a number of development paths for solid-state anodes, as well as the evolution from Li-ion to safe, rechargeable Li metal batteries.

Fig. 1. Schematic representation of glass protected Li metal electrodes for next generation cells.

Li-ion batteries are the most promising energy storage systems for electric vehicles (EV) and hybrid plug-in electric vehicles (HPEV). Key issues in the development of new generation storage materials are cost reduction, availability of raw materials, environmental benignity, and increase in energy density and safety.

The first commercially available Li-ion battery system used LiCoO$_2$ as cathode material and graphite for the anode. Nowadays, state of the art cathode materials are LiMn$_2$O$_4$ (LMS), LiNi$_{1-x-y}$Mn$_x$Co$_y$O$_2$ (NMC), LiNi$_{0.80}$Co$_{0.15}$Al$_{0.05}$O$_2$ (NCA) and LiFePO$_4$ (LFP). The mainly used anode material is still graphite. Increasing energy density is one of the main targets for automotive applications. During the last years several new classes of active materials with promising properties have been discovered and lot of research activities focus on implementing these materials into cells. Nevertheless, only few materials find their way from the lab into the market, and during the last years the progress in specific energy and energy density of commercial cells was mainly due to optimization of electrode and cell design. When going from a material to LIB full cell, different parameters are of importance, as shown in Fig.1.
On material level chemistry and crystal structure determine the function of a storage material. The electrochemical assessment of these materials is based on half-cell measurements with metallic lithium as counter and reference electrode. Function and applicability of a material are described by material related properties, such as specific capacity, potential characteristic and cycle life.

When going into full cells, electrode and electrode-stack related properties become important. Key parameters are now areal loading (mAh/cm²) and volumetric capacity (mAh/cm³) of the electrodes. In a full cell cathode and anode act in concert, and their individual storage capability and kinetics have to be properly adjusted (balanced) to maximize material utilization and cell life. All electrochemically active lithium is introduced by the cathode, and initial irreversible capacity losses, easy to handle on pure material level, might become limiting for application in full cells.

Finally, for cell production, the role of production process and related cost become determining factors. Cells are assessed in terms of their specific energy (Wh/kg), energy density (Wh/l) and cost (€/Wh).

The talk will present these key factors for selected materials.
Translating Electrochemistry Into Energy Products - a Personal View

N. P. Brandon

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Imperial College London

The paper will present the authors own experience in spinning out a fuel cell company, Ceres Power, based on research conducted at Imperial College London, and the subsequent development of the company over the past 15 years. Recent examples of new innovations arising from the authors work on electrochemical energy storage will also be introduced, and conclusions drawn about the opportunities and challenges facing academic researchers seeking to translate new science into new products, with a focus on electrochemical sciences and their application in the energy sector.
The Pursuit and Discovery of Vehicle Electrification Markets

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General Motors, Global Propulsion System Development, Pontiac, MI, USA

Whereas it is clear that we are moving towards less-petroleum-based and lower-carbon-footprint transportation technologies, the outcome and pace of this evolution will be determined by difficult to predict factors. These include trajectories in vehicle technology and cost, energy generation/distribution technology and cost, priority given to environmental factors, and public acceptance of new technologies and ownership models. The uncertainties in these trajectories are quite large, making it difficult to predict which technology will dominate or if multiple technologies will be successfully commercialized. Moreover, the potential outcomes will depend largely on the evolution of national energy systems, each of which depends on regional natural resource availability. For example, a critical question is whether it will make economic sense to produce hydrogen from electrolysis using excess renewable energy. The answer to that question in turn depends on whether flow-battery technology becomes an economic approach to load-leveling the electricity grid. Whereas we cannot be sure of the ultimate methods we will use to achieve a zero-emission personal-mobility market, we can be assured that electrochemists and electrochemical engineers will play a critical role in discovering it.
Hydrogen Limbo: How Low Can We Go?

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Interest in hydrogen, always vulnerable to the changing winds of government and industrial interest once again finds itself at a peak. Electrolysis of water, when coupled with renewable energy is generally accepted as the only carbon-free method of hydrogen production. Alkaline hydrolysis which has long been the work-horse of large-scale electrolysis is generally being replaced by PEM (polymer electrolyte membrane) due to the latter’s higher efficiency, and ability to provide higher and differential pressure. Subsequently there are more and more providers of large-scale PEM systems. Despite this there is little agreement on what the cost of that hydrogen will be. Charlie Freese, executive director-global fuel cell activities at General Motors recently gave a target of $0.57/kg.\(^1\) Traditional suppliers of hydrogen from centralized reformation will state that this is ridiculous, and point to the fact that current prices at California stations are $16.00/kg, using natural gas, which is currently the cheapest method to supply hydrogen.

Who to believe? This talk will look at the underlying costs of hydrogen from electrolysis. It will also look at the opportunities and the technical challenges of lowering both capital and operating expenditures. Specifically, the role of noble metals, often the focus of PEM research funding, will show that they do not contribute significantly to the cost of electrolysis at current usage. At meaningful scale however there are real concerns on supply, especially of Ir, the rarest naturally occurring metal. Finally much of the assumptions of low-cost hydrogen from electrolysis is based on cheap, or even free energy from excess renewables. Taking advantage of these low-cost intermittent sources can greatly reduce the utilization of the electrolysis capital equipment however, greatly increasing capital costs.

List of Participants

SCCER Heat & Electricity Storage 5th Symposium

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